10 Little Gibbs Rd
Malabar Hill
Bombay.
10. Nov. 1938.

Dear Professor Madhava Rao,

Thank you for your kind letter of the 7th. I am afraid that I have no reprints with me here in India at all, and therefore cannot send you any. They are all in Cambridge.

I shall try and send you the Solvay reports soon, but they are rather bulky and it might be a few days before I get them suitably packed.

By coming to Bangalore has not been finally settled by the Council yet, but should it be passed, I expect to be in Bangalore for a couple of months from the

beginning of January.

In the meantime I would like to draw your attention to the following problem and ask you to let me know if you would care to collaborate with me on it. The problem is to calculate the "Compton effect" of γ-rays on charged mesons. The interaction of mesons with electromagnetic radiation is given in my paper. This problem is <u>rather important</u> for by the Weizsäcker method, it is directly connected with the Bremsstrahlung. I had put a research student in Cambridge onto the latter problem, and now A.H. Wilson is helping him. But it is extremely complicated. Moreover, the Weizsäcker method gives one more physical insight into the problem. So it would be very interesting to know the Compton effect. Could you

perhaps study this problem and start working on it. I am at the moment still engaged on the spinning particle. I have now reason to believe that it is wrong to describe protons by the Dirac equation as far as nuclear theory is concerned.

Returning to the Compton effect, it should be noted that a contribution comes

1) by a second order process from the terms containing e of expression (55) of my paper, and

2) by a first-order process from the terms containing e^2 of (55) of this paper.

2) I have heard from America that some pupils of Oppenheimer have tried the Bremsstrahlung problem and find that the radiation loss increases as E^2 (E energy of meson) whereas for Dirac particles it increases as E.

Our Compton effect would give an insight into this, and show why this happens (if it is true). In fact this might be crucial for the meson theory in confirming or refuting it.

With kind regards

Yours sincerely

H. J. Bhabha

8 Little Gibbs Rd
Malabar Hill
Bombay
18 May 1940

My dear Madhava Rao,

Thank you very much for so kindly sending me a report on Mukherji's Thesis. I have had it typed, written a report on his past paper, and added a summing up. I have mentioned in a covering note that the remarks on papers 2-6 are due to you and that I have complete faith in your judgement. I think the thesis will have been as fairly examined as is possible in India. In my summing up, I state that the candidate expositon is clear & concise. that he does not show much originality, but that may perhaps be due to environment. I end by saying that if the candidate were enabled to do research for some time in contact with an outstanding scientist in touch with the newest developments in physics, then he might do

work of much value. I think that is perhaps a fair estimate of the case. The other thesis I examined certainly does not deserve the award of the studentship.

My appointment to Calcutta seems to have appeared in the papers*, but I have not heard officially from the University yet! In any case, I shall not be going there till the end of July, and intend spending about a fortnight there. I hope to come to Bangalore at the beginning of June. Bombay is terribly hot & damp. I hope B'lore is more pleasant than when I left.

Things in Europe are beginning to look serious, but I still do not believe that the Allies will lose. I hope your reading is going well. As soon as I start writing my book, I shall have a number of problems requiring work. One of them might interest you. I am having a complete rest

With kind regards

Yours sincerely

H. Bhabha.

P.S. Will you kindly ask Sir C.V. Raman if he has got the errata for my two papers which I sent a week ago? I should also like 6 copies of the reprints of both my papers sent to me at once. If not, it would be better to

* I should like to see it.

P.S. About a week ago I sent the errata for both my papers to Sir C. V. Raman. I hope these will be set up at once so that the slips could be printed off, stuck into the reprints & these then posted. I hope I won't have to wait till the end of the month for these: I ~~should like~~ must have proofs of the errata slips. These may be sent here. I will return them by return post after correction.

I also would like to have 6 reprints of ~~those~~ each of my two papers. Could these be despatched to me at once (i.e. without the errata slips!) I should be grateful if you could ask Venkatachar about this.

F Little Gibbs Rd
Malabar Hill
Bombay
27 May 40.

My Dear Radhava Rao,

I have just returned to
M/s Venkatachar the corrected proofs of
my errata slips. Unfortunately they still
require a number of corrections. As they
will not have time to send me further
proofs, I have requested that they send
you the corrected proofs together with my
~~copies~~ the typescripts of these errata slips.
I should be very grateful if you would
kindly do me the favour of correcting
the same for me. I am anxious that
no single misprint should occur in the

errata slips.

The hot and damp climate of Bombay has got me down, & I have broken out with a number of boils which have troubled me the last few days. However, they are now subsiding.

I hope your work is going well. I have got a letter from Paul about my question as to the reduction of the Dirac equation to the Hamilton Jacobi eqn: when a $g_{\mu\nu}$ term is present. He says he has not done this himself, but the result ought to be that of geometrical optics, given for example, two beams in a magnetic field. I cannot see how this happens, but the problem might be worth tackling seriously.

With kindest regards

Yours very sincerely

H. J. Bhabha

P.S. I quote Pauli "The result of the formalism must be similar to geometrical optics in the presence of a magnetic field (two different rays with different polarisations because of the Faraday effect)."

I shall be in Bangalore soon after the beginning of June.

I have been expecting to hear from Sir C.V. but have not done so. Is he away? Kindly give him my kindest regards

Great Eastern Hotel

Calcutta

2 Dec. 1940.

Dear Madhava Rao,

While in the train I thought of a slight mistake in our calculations. $\left| \frac{H(i0|m)(m|H|0i)}{E_i - E_m} \right|$ must be proportional to $\frac{1}{V}$ not V as I put down. This is because the wave functions of the heavy particles, which we have not given explicitly in the paper, have a normalising factor $\frac{1}{\sqrt{V}}$. Thus, your original expression with $\frac{1}{V}$ was right for $|\ |$. As a result

$$dQ = \ldots V^2 |\ |^2 d\Omega$$

and not

$$dQ = \ldots \frac{1}{V^2} |\ |^2 d\Omega.$$

Please make these two corrections.

Thank you very much for coming to see me yesterday. I thought Sir C. V. R. conducted a little strangely at the end when he walked away. I felt he was offended about something — I don't know what. Please tell me frankly if he could

any thing to you afterwards. I shall then try & rectify the matter.

Do & try & get the help numbers in the Dec. number of the Indian Head. And there must be no misprint, the time not even in the language.

Thank you for your contribution. I hope to see you within a couple of months. With best wishes

Yours

H. B Lotha

P.S. Please write to me at the first Eastern Hotel & mark your letter "To await" for me till the 9th.

HOTEL TELEPHONE NOS 253 254
OFFICE TELEPHONE No 255

POST BOX 192

THE GREAT EASTERN HOTEL LD.

TELEGRAMS
"GREASTERN CALCUTTA"
CODES
A B C 4TH & 5TH EDITIONS A1 AND BENTLEY'S

CALCUTTA 14. Dec. 194

My dear Venkata Rao,

Thank you for the manuscript of our paper & the meson manuscript, as also the Phys. Rev. letter. I find there are some misprints in the paper & I hasten to inform you of them. I also think that it is bad policy to have $c=1$ in part of the paper & $c \neq 1$ in the rest: it is not even as if the $c=1$ consistently in the whole of the classical section. In the corrections I give below, I have therefore added the appropriate powers of c.

p. 2. line 12 add "(cf. Heitler 1940)" after "classical theory".

p. 3 line 12, insert "constant" before "numerical".

p. 3 line 18 let there read "for a Maxwell field by Bhabha (12 and Bhabha & Corben*, and for a meson field by Bhabha* ($1940\frac{c}{=}$)".

p. 6. third line after (57). "intermediate" instead of "final". read "of the initial & intermediate states of the whole syste

HOTEL TELEPHONE NOS 253 254
OFFICE TELEPHONE NO 255

POST BOX 192

THE GREAT EASTERN HOTEL LD.

TELEGRAMS
"GREASTERN CALCUTTA"
CODES
A B C 4TH & 5TH EDITIONS A1 AND BENTLEY'S

2

CALCUTTA 19

eq. 10. insert $d\Omega$ at end.

p. 11, second line before (20), substitute "each of" for "all".
to read "cross-section for each of the ions ..."

p. 12. line 1, read "Bhabha in a recent letter (1940c)".

p. 12. line 10, insert c before ω_0, thus "meson wave
of frequency $c\omega_0$ with ..."

Eq (21). "cos $c\omega_0 t -$ ".

Eq (22). $\frac{H_0^2}{8\pi} \frac{c\omega_0 \mathcal{V}}{(\omega_0^2 - \chi^2)^{1/2}}$

Eq (23) "sin $c\omega_0 t -$".

Eq (24) $|M_1| = \frac{g_2 H_0 \sin\phi}{I c \omega_0}$

p. 13 ~~bare~~ third line after (24), substitute "Eq (23) are" instead
of "Eq (22) are".

eq (25) change to "cos $\{c\omega_0 t - \kappa\sqrt{\omega_0^2 - \chi^2}\}$".

eq (27) $\frac{1}{8\pi} g_2^2 \frac{c\omega_0 (\omega_0^2 - \chi^2)^{3/2}}{\kappa^4} [\underline{\kappa} * \underline{M}_1]^2$

eq (28). } ~~omit $c^2 I^2$ instead of I^2~~
eq (30a) } insert c^2 in denominator, i.e. omit
eq. (30b) } $\xi c^2 \omega_0^2 \Xi$ in place of ω_0^2

HOTEL TELEPHONE NOS 253 254
OFFICE TELEPHONE NO 255

POST BOX 192

THE GREAT EASTERN HOTEL LD.

TELEGRAMS
"GREASTERN CALCUTTA"
CODES
A B C 4TH & 5TH EDITIONS A1 AND BENTLEY'S

CALCUTTA 19

f. 16 line 10 read "The ... $= -r|M_1|\sin\chi_1, \ldots$"

eq (33c) should read

$$dQ'\{\ \} = \frac{g_2^4}{\hbar^2 I^2}\,\frac{(\omega_0^2-x^2)^2}{c^2\omega_0^2}\sin^2\phi\sin^2\chi_1\,d\Omega$$

$$= \frac{g_2^4}{\hbar^2 I^2}\cdot\frac{(\omega_0^2-x^2)^2}{c^2\omega_0^2}\cos^2\chi_0\,d\Omega .$$

f. 17 line 1 substitute "(31)" for "(32)". "$\cos^2\chi_0$" instead of "cos"
f. 17 line 2
eq (33b) substitute "$c^2\omega_0^2$" for "ω_0^2" in denominator.

The next equation should read

$$(\Sigma_{f'}\cdot[\underline{r}\times\underline{M}_1]) = \ldots = r|M_1|\cos\chi_1\sin\theta .$$

The next equation

$$dQ'\{(1f)\to(1f')\} = \frac{g_2^4}{\hbar^2 I^2}\,\frac{(\omega_0^2-x^2)^2}{c^2\omega_0^2}\sin^2\theta\sin^2\phi\cos^2\chi_1\,d\Omega .$$

Eq (34c) reads which, by (32) reduces to

$$dQ'\{(1f)\to(1f')\} = \frac{g_2^4}{\hbar^2 I^2}\,\frac{(\omega_0^2-x^2)^2}{c^2\omega_0^2}\sin^2\theta\cos^2\chi_0\,d\Omega$$

Two lines down read "$\cos^2\chi_0$ by $1/3$", instead of "$\cos^2\chi_0$ by $1/3$"

Eq (34b)
Eq (35)
Eq (36a)
} Substitute "$c^2\omega_0^2$" for "ω_0^2" in denominator

In ~~next line~~ (36b) read

"where $\alpha = 3Ic/2g_2^2$."

HOTEL TELEPHONE NOS 253 254
OFFICE TELEPHONE No 255

POST BOX 192

THE GREAT EASTERN HOTEL LD.

TELEGRAMS
"GREASTERN CALCUTTA"
CODES
A B C 4TH & 5TH EDITIONS A1 AND BENTLEY'S

CALCUTTA 19

4

p 18. fourth line after (36c)
"$E = c\hbar\omega_0$" instead of "$E = \hbar\omega_0$"

Eq (37). Write "$c^2\omega_0^2$" for "ω_0^2" in denominator

(P.T.O.)

p. 21 line 12 insert "the" before "quantum"; to read "between the quantum".

p 21 line 20, change "would only seriously go wrong due to" to "would only go wrong seriously due to".

p 22 line 12. "on energy" instead of "of energy"

p 22 line 21 "It shows ...." should not start a new paragraph.
Insert "also", thus "It also shows that ---".

p 23 line 1 read "by the factor $3(1 - 4\hbar\omega c^2/E)$ for --
p. 24. line 9, substitute "Bhabha" instead of "one of us".
p. 24 line 16, ~~transfer~~ final sentence "Thus on the assumption the scattering of charged mesons shows complete correspondence with the classical theory, ..." in italics.

Head of Col. of last column of Table

$(4 g_2'^4 \hbar^4 / 3 \mu^4 c^4 E^2) d\Omega$

instead of $(\frac{4}{3} \pi'^4 \hbar^4 / \mu^4 c^4 E^2) d\Omega$

HOTEL TELEPHONE NOS 253 254
OFFICE TELEPHONE NO 255

POST BOX 192

THE GREAT EASTERN HOTEL LD.

TELEGRAMS
"GREASTERN CALCUTTA"
CODES
A B C 4TH & 5TH EDITIONS A1 AND BENTLEY'S

5 CALCUTTA 19

For in the reference, I think we should follow the Royal Society practice, which is also that I shall use in my forthcoming Lectures in the Academy, thus.

Bhabha 1938 Proc. Roy. Soc. A, 166, 501–22

1939 ibid 172, 384–408.

1940a Proc. Indian Acad. Sci. A, 11, 247–67, 467

1940b ibid 11, 347–68, 468.

1940c Proc. Roy. Soc. A, in print.

Heitler 1940 Nature 145, 29–30.

In figure I, the angle $M_0 H_0$ should be marked as ϕ. Since in the text the axes are referred to as x, y, z, small letters should be used in both figure and not X, Y, Z.

I think this finishes all the errata. Then check the c factors. This you can easily do remembering that

q_2 = charge × length,

ω_0 = 1/length,

$H = E$ = √energy/volume

I am very keen that the painting
[illegible] should be hand-done. I do not mind
it appearing in the January issue instead of
the December issue. After all, there is no
urgency in it. But under all circumstances
all the above corrections must be carried
carried out & two new ones must be taken.
I've had better ones for 3 years.

I think the figures should be drawn
beautifully by the fashion artist. I am writing
to Lee C.V. to this effect. It will look
much nicer.

I hope you are having a nice time.
My own health has been rather bad. With
kind regards

Yours sincerely
K. L. Bhandari

2 Little Gibbs Rd
Malabar Hill
Bombay
24 Jan. 41

Dear Madhava Rao,

I am trying to catch today's mail. I got your proofs only yesterday when I returned.

There are a number of corrections. Most important are certain mistakes on p. 13, 14 & 15 which I have corrected. I have added a paragraph at the end of the section & a line at the end of the summary.

The alteration in (27) makes the later references to this formula more intelligible.

There is one correction I have made in pencil. In (5) you have $(\ell\, l_0 / m)(m / l_0 i)$ whereas on top of p. 8 you have $(i / l_0 / m)(m / l_0 / \ell)$. Why this change? I think it should be corrected there and below. Alternatively make formula (5) read $(i / l_0 / m)(m / l_0 / \ell)$. I leave this to you to decide.

The other corrections must be made.

The letter in (4) is capital script I not Θ (Greek theta). I should like this changed, but if they have no such letter, it may be left as Θ.

I hope it is not too late to get 5 altered. Otherwise the paper must be delayed till Feb. as some of the corrections I think I am afraid you will have to get another proof to make sure they have committed no new mistakes in resetting. I trust this & my cost when my last head. paper came out.

When ready 5 this letter I shall be in B'ham on the 2nd Feb.

With great haste

Yrs

H. F. Blanford

The inverted

Bombay
24 Jan. 41.

Dear Madhava Rao,

I have just posted the corrected proofs of our paper to you registered. I forgot to mention one point. The angles ψ_0, ϕ_0, & θ_0 are correct as they stand in the proof. I had made a mistake when I wrote to you last time.

The point of ε, α, and σ will do. If there is nothing better to be done about it.

I have got Pauli's letter & will give it to you when I return. I am not satisfied with Pauli's solution. You might tackle this problem next. I shall only be satisfied when you get out the equations for the rotation of the spin namely

$$\tfrac{1}{2}\hbar\dot{\sigma} = g_2[\sigma \cdot H]$$

out of the Dirac[1]* equations with a g_2 term. You will notice that $\hbar$ has to appear explicitly in the equation.

Please do not let the paper go through

without the corrections I have sent about the scattering of positive & negative mesons. What is had there is definitely wrong.

$$\left\{ y^+ + p \rightarrow \left\{ \begin{matrix} p_2 \\ y^+ + n + y^{+\prime} \end{matrix} \right\} \rightarrow y^{+\prime} + p \right.$$

$$y^{+-} + p \rightarrow \left\{ y^- + p_2 + y^{-\prime} \right\} \rightarrow y^{-\prime} + p.$$

The other case you can also verify.

Please also insert the para. about Heitler & Ma.

Yours sincerely

H. J. Bhabha.

Sl – Auns
Ootacamund
10 Nov. 41

(1)

My dear Madhava Rao,

There is one very queer point which Bau & I have come across. It is that 2nd order processes calculated on the basis of the theory (a) that all the negative energy states of the electron or other Dirac particle (spin 1/2) are empty is not the same as when calculated on the assumption (b) that all the negative energy states are full. (Dirac - hole theory) This result is so fundamental that I can hardly believe that all previous workers including myself have made the same mistake. As I see it, assumption (a) gives the Klein-Nishina formula, (b) does not. To my knowledge there is only one occasion on which the discrepancy has been noticed, namely the calculation of the 2nd order self-

energy / an electron by Weisskopf, in which (a) &
(b) / give different results. If I am right in
thinking that (a) + (b) give different results, the
it would be a very severe blow to "hole" theory.

I would therefore like to have an independent
check on this point and would therefore be very
grateful if you would independently just confirm
the difference in sign of one term between (a) &
(b). If you get into touch with Dr. Bacon at
the Indian Institute of Science, he will explain
everything to you. I have written to him.

I shall be in Bâle by the 15th
& will see you a day or two after that.

With kind regards,

Yours sincerely,

H. J. Shabha.